

Historical Overview of the Development of United States, Canadian, and Mexican Ecosystem Sources and Sinks for Atmospheric Carbon

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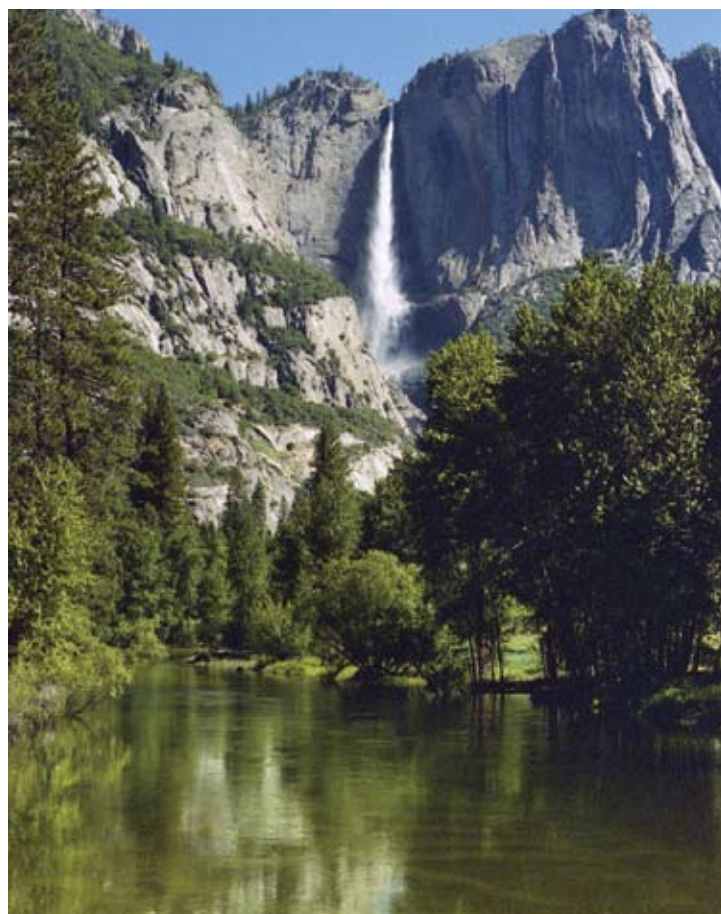
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Although the lands of the New World were inhabited before the arrival of Europeans, the changes since arrival have been enormous, especially during the last two centuries. Peak United States emissions from land-use change occurred late in the nineteenth century, and the last few decades have experienced a carbon sink (Houghton *et al.*, 1999; Hurtt *et al.*, 2002). In Canada, peak emissions occurred nearly a century later than in the United States, and current data show that land-use change causes a net carbon sink (Environment Canada, 2005). In Mexico, the emissions of carbon continue to increase from net deforestation. All three countries may be in different stages of the same development pattern (Figure 3.2)

The largest changes in land use and the largest emissions of carbon came from the expansion of croplands. In addition to the carbon lost from trees, soils lose 25-30% of their initial carbon content (to a depth of 1 m) when cultivated. In the United States, croplands increased from about 0.25 million hectares (ha) in 1700 to 236 million ha in 1990 (Houghton *et al.*, 1999; Houghton and Hackler, 2000). The most rapid expansion (and the largest emissions) occurred between 1800 and 1900, and since 1920, there has been little net change in cropland area. Pastures expanded nearly as much, from 0.01 million to 231 million ha, most of the increase

taking place between 1850 and 1950. As most pastures were derived from grasslands, the associated changes in carbon stocks were modest.

The total area of forests and woodlands in the United States declined as a result of agricultural expansion by



160 million ha (38%), but this net change obscures the dynamics of forest loss and recovery, especially in the eastern part of the United States. After 1920, forest areas increased by 14 million ha nationwide as farmlands continued to be abandoned in the northeast, southeast, and north central regions. Nevertheless, another 4 million ha of forest were lost in other regions, and the net recovery of 10 million ha offset only 6% of the net loss (Houghton and Hackler, 2000).

Between 1938 and 2002, the total area of forestland in the conterminous United States decreased slightly, by 3 million ha (Smith *et al.*, 2004). This small change is the net result of much larger shifts among land-use classes (Birdsey and Lewis, 2003). Gains of forestland, primarily from cropland and pasture, were about 50 million ha for this period. Losses of forestland to cropland, pasture, and developed use were about 53 million ha for the same period. Gains of forestland were primarily in the Eastern United States, whereas losses to cropland and pasture were predominantly in the South, and losses to developed use were spread around all regions of the United States.

In the United States, harvest of industrial wood (timber) generally followed the periods of major agricultural clearing in each region. In the last few decades, total volume harvested increased until a recent leveling took place (Smith *et al.*, 2004). The volume harvested in the Pacific Coast and Rocky Mountain regions has declined sharply, whereas harvest in the South increased and in the North, stayed level. Fuel wood harvest peaked between 1860 and 1880, after which fossil fuels became the dominant type of fuel (Houghton and Hackler, 2000).

The arrival of Europeans reduced the area annually burned, but a federal program of fire protection was not established until early in the twentieth century. Fire exclusion had begun earlier in California and in parts of the central, mountain, and Pacific regions. However, neither the extent nor the timing of early fire exclusion is well known. After about 1920, the Cooperative Fire Protection Program gradually reduced the areas annually burned by wildfires (Houghton *et al.*, 1999, 2000). The reduction in wildfires led to an increase in carbon storage in forests. How long this “recovery” will last is unclear. There is some evidence that fires are becoming more widespread again, especially in Canada and the western United States. Fire exclusion and suppression are also thought to have led to woody encroachment, especially in the southwestern and western United States. The extent and rate of this process is poorly documented, however, and estimates of a carbon sink are very uncertain. Gains in carbon above-ground may be offset by losses below-ground in some systems, and the spread of exotic annual grasses into semiarid deserts and shrublands may be converting the recent sink to a source (Bradley *et al.*, in preparation).

The consequence of this land-use history is that United States’ forests, at present, are recovering from agricultural abandonment, fire suppression, and reduced logging (in some regions), and as a result, are accumulating carbon (Birdsey and Heath, 1995; Houghton *et al.*, 1999; Caspersen *et al.*, 2000; Pacala *et al.*, 2001). The magnitude of the sink is uncertain, and whether any of it has been enhanced by environmental change (CO₂ fertilization, nitrogen deposition, and changes in climate) is unclear. Understanding the mechanisms responsible for the current sink is important for predicting its future behavior (Hurt *et al.*, 2002).

In the mid-1980s, Mexico lost approximately 668,000 ha of closed forests annually, about 75% of them tropical forests (Masera *et al.*, 1997). Most deforestation was for pastures. Another 136,000 ha of forest suffered major perturbations, and the net flux of carbon from deforestation, logging, fires, degradation, and the establishment of plantations was 52.3 million tons of carbon per year, about 40% of the country’s estimated annual emissions of carbon. A later study found the deforestation rate for tropical Mexico to be about 12% higher (1.9% per year) (Cairns *et al.*, 2000).